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Electrochemical Noise Sensors for Detection of Localized and General Corrosion of Natural Gas Transmission Pipelines

Gordon Holcomb, Sophie Bullard, Bernard
Covino, Stephen Cramer, James Russell,
Margaret Ziomek-Moroz



National Energy Technology Laboratory



Strategic Center for Natural Gas

Natural Gas Infrastructure Reliability

Inspection

Natural Gas Infrastructure Reliability Industry Forums

September 16-17, 2002

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Corrosion Monitoring Methods

Real-Time Monitoring

After-the-fact Detection

Linear Polarization

Coupons

Harmonic Distortion

Section Loss Measurements

Electrochemical Impedance
Spectroscopy

Crack and Pit Detection

Electrochemical Noise

Failure Analysis



Outline

- Purpose
- Electrochemical Noise and Sensors
- Year One Tests
- Conclusions
- Future Work



Purpose

To demonstrate the use of electrochemical noise (EN) sensors for measuring the internal and external corrosion of natural gas transmission pipelines.



Principles of EN

- Potentials – equilibrium driving forces
- Currents – kinetics of corrosion
- Signal noise in potentials or currents from one spot on a surface to another creates a “signature” to be interpreted.
- Isolation of the different locations allows the signal to be measured.



What are EN Sensors?

- 2 or 3 isolated pieces of pipeline metal (electrodes)
- Fixed in place
- Sensor signals collected and analyzed at computers remote from the sensors

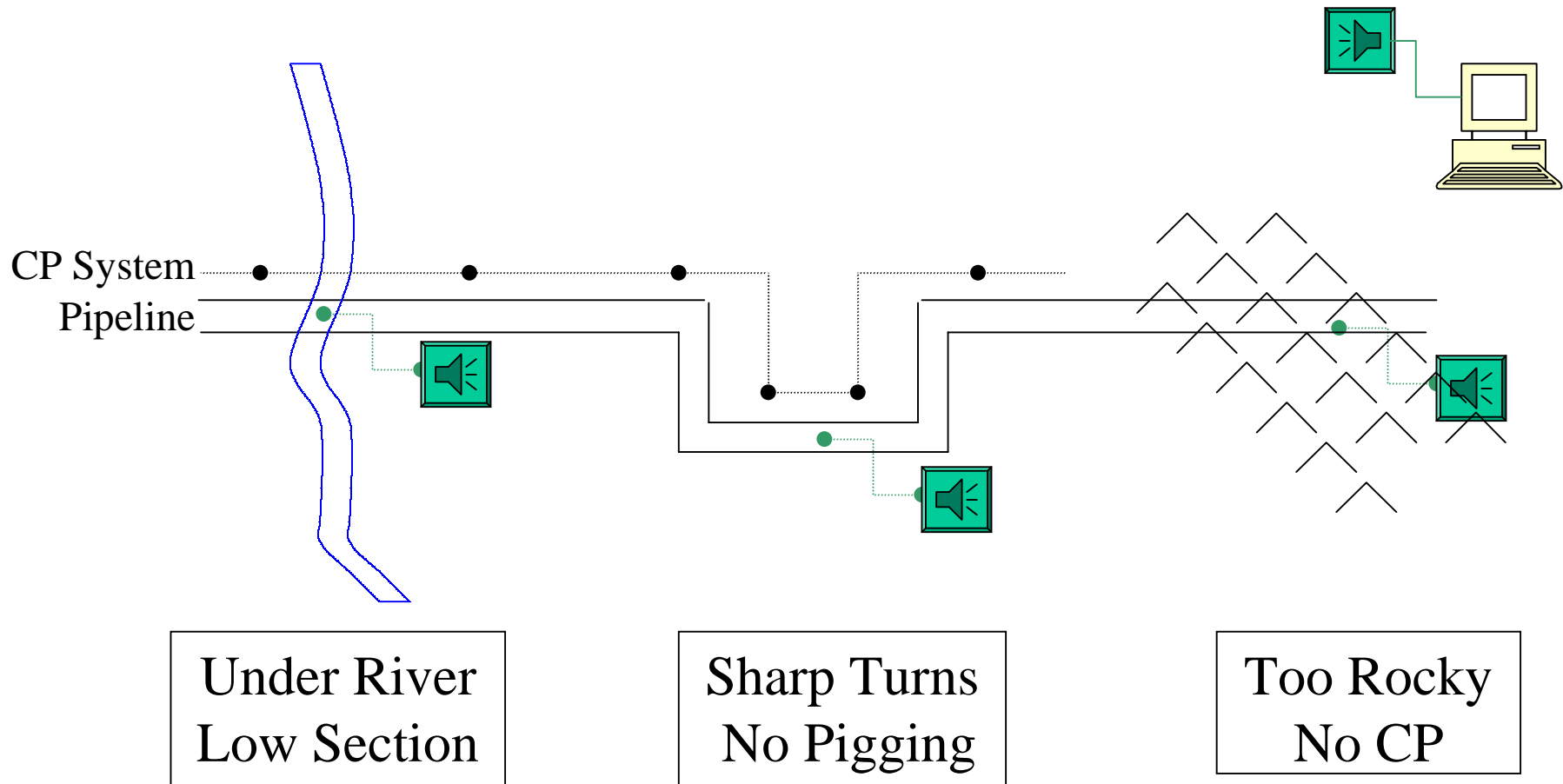


EN Sensor Placement

- Internal Placement – Areas of Interest
 - Low points that collect water
 - Following compressors (higher temperatures)
 - Limited pigging sections
- External Placement – Areas of Interest
 - Areas without CP



EN Sensor Array





Internal Sensors Flanges or Inserts



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Internal Sensors

Contoured Inserts





External Sensors

- Much like coupons currently used in CP systems
- Could be stressed to give SCC tendencies
- For systems without CP



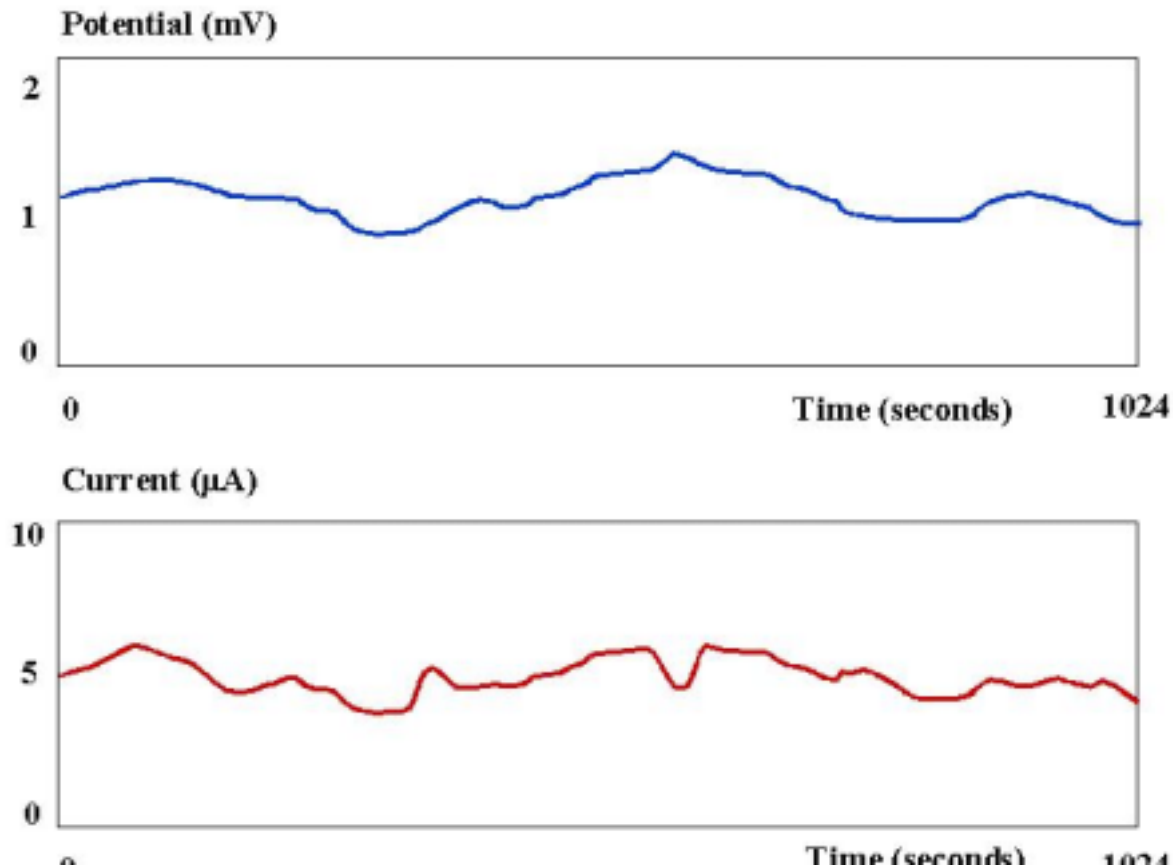
Detection Capabilities

- Corrosion levels
 - Monitoring history gives cumulative section loss
 - Inhibitor effectiveness
- Corrosion types
 - General, pitting, SCC
- Flow types (e.g. slugging in 2-phase flow)
- Chemistry indications of corrosive species (CO₂ and O₂ levels)



General Corrosion

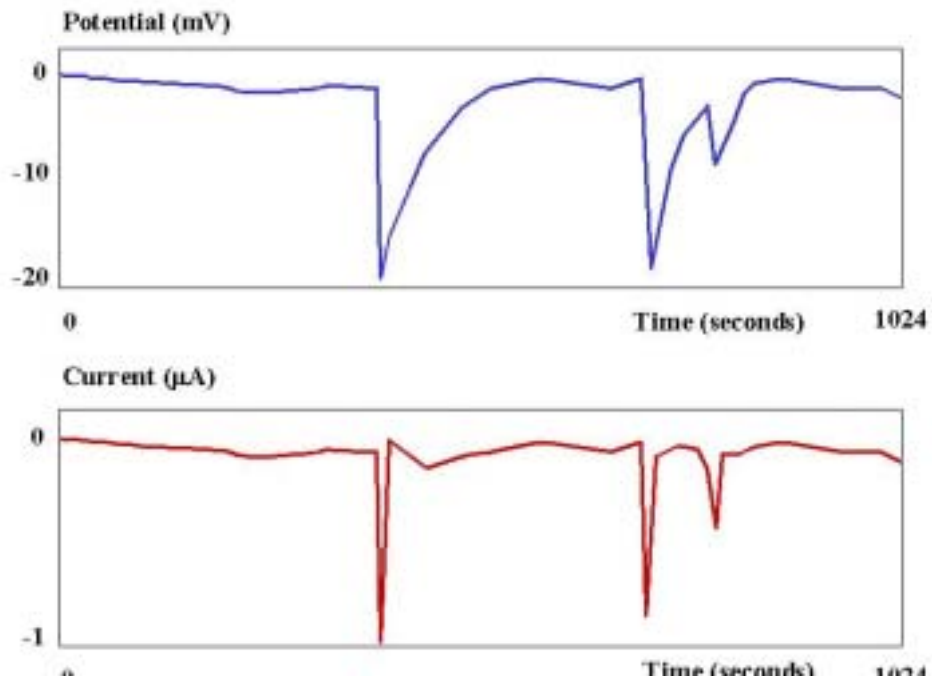
General Corrosion



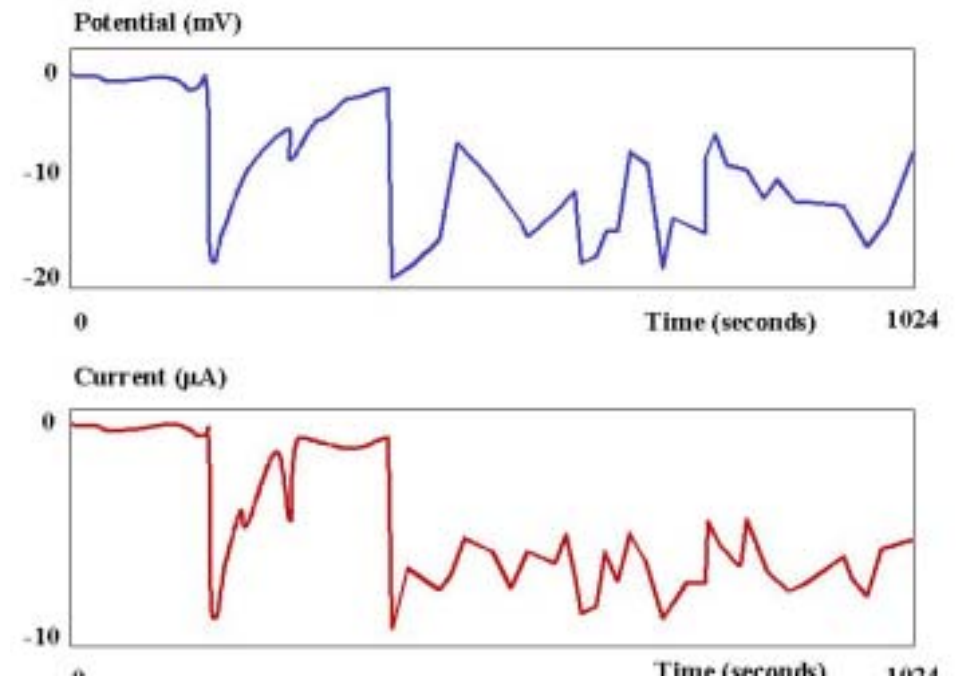


Pitting

Pitting Initiation



Pitting Propagation





Signal Interpretation - Tools

- Visual
- Sequence independent
 - Mean
 - Standard deviation
 - Skewness (deviation from normal distribution tails)
 - Kurtosis (deviation from normal distribution peak)
- Sequence dependent
 - Power Spectra
 - Chaos theory



Year One

Demonstration Project Tests

- Commercial Unit
- External Corrosion
- Internal Corrosion



Commercial EN System



- Easy Implementation to Field and Industry Use
- Intrinsically Safe
- EN, LP, and Harmonic Distortion Analysis
- No Sequence Dependent Analysis
- Converts and Doesn't Save Raw Data



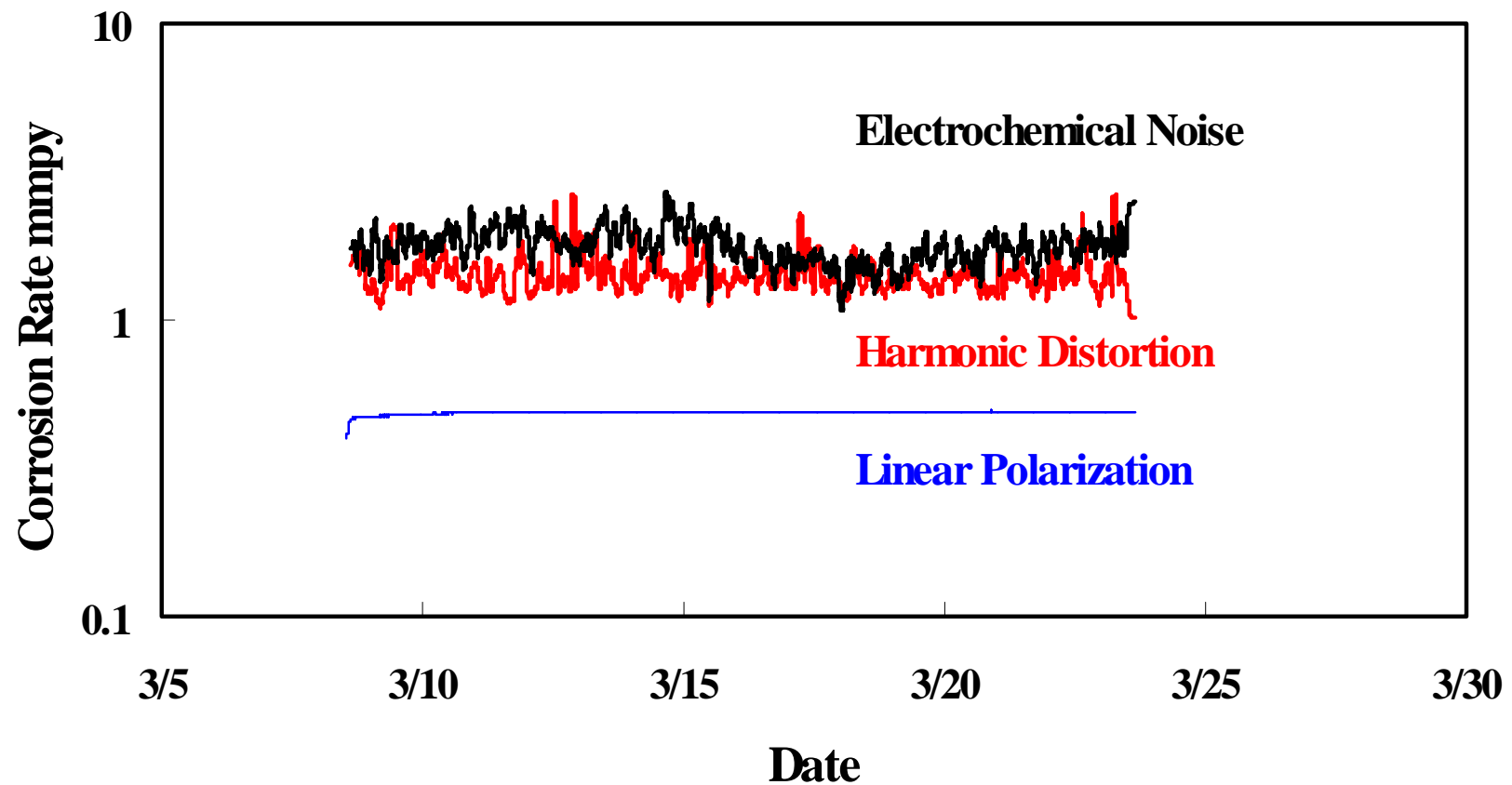
Internal and External

Aqueous Corrosion Test



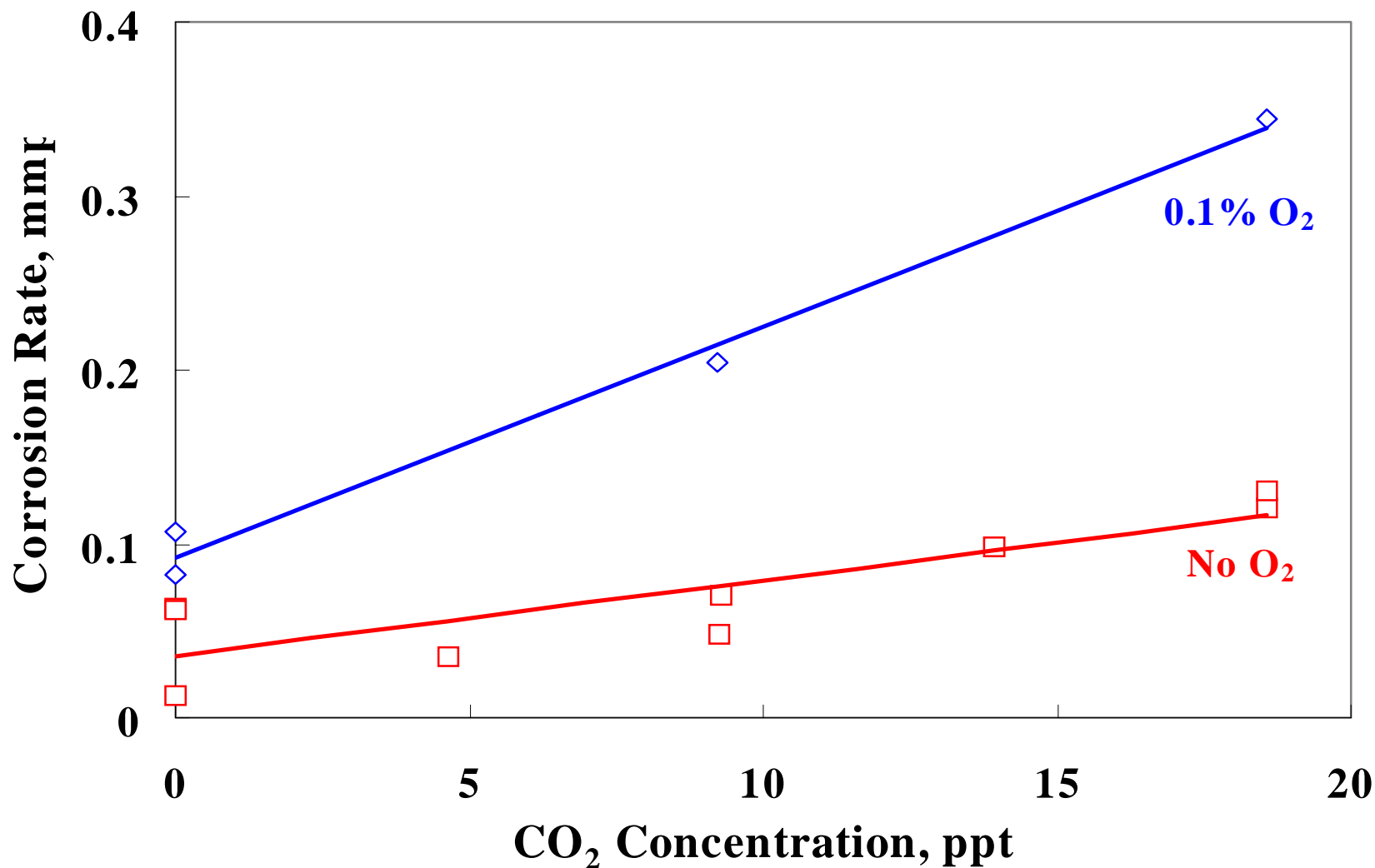


0.5 N H₂SO₄





3.5% NaCl





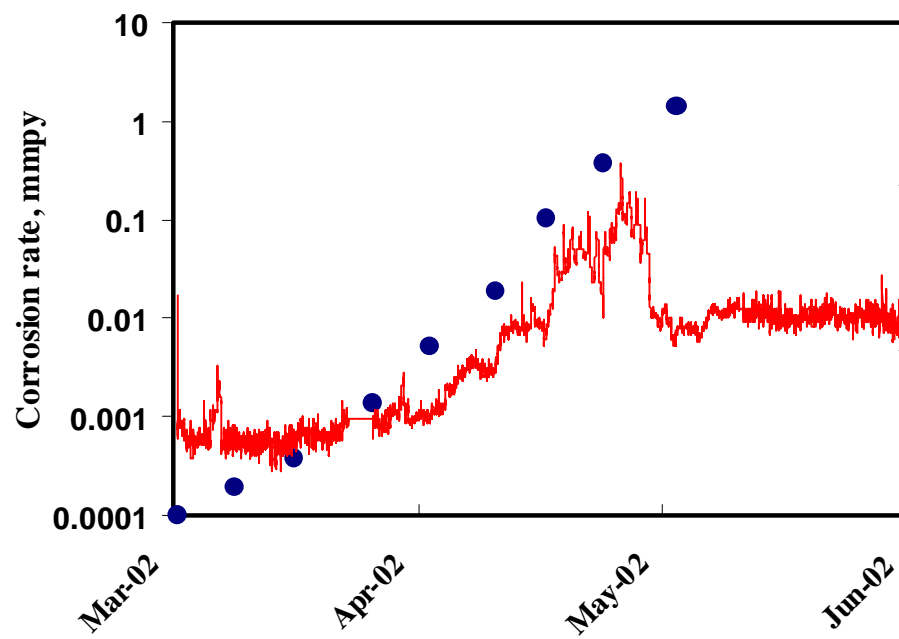
External Corrosion Soil Corrosion Test



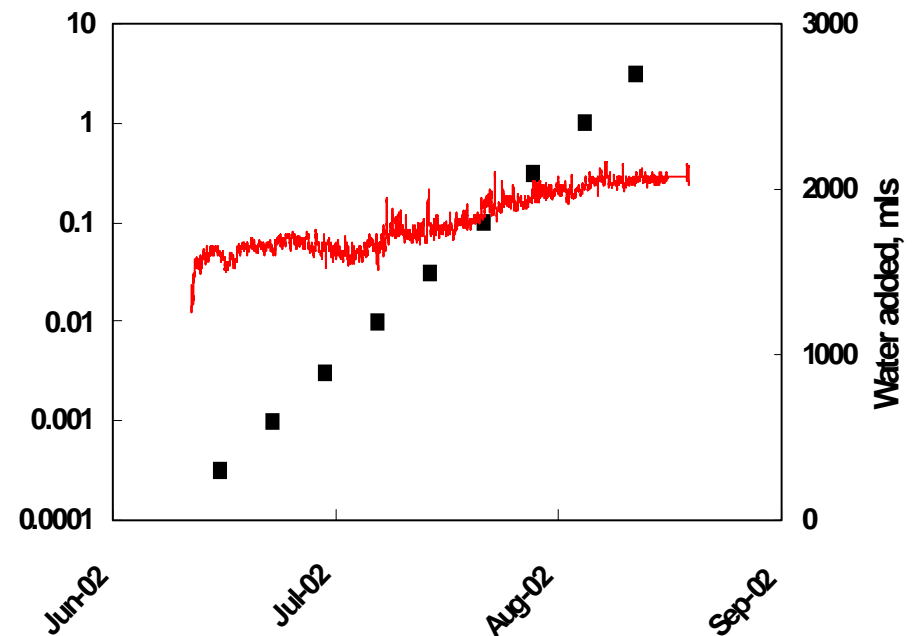


Corrosion Tests in Soil

Soil

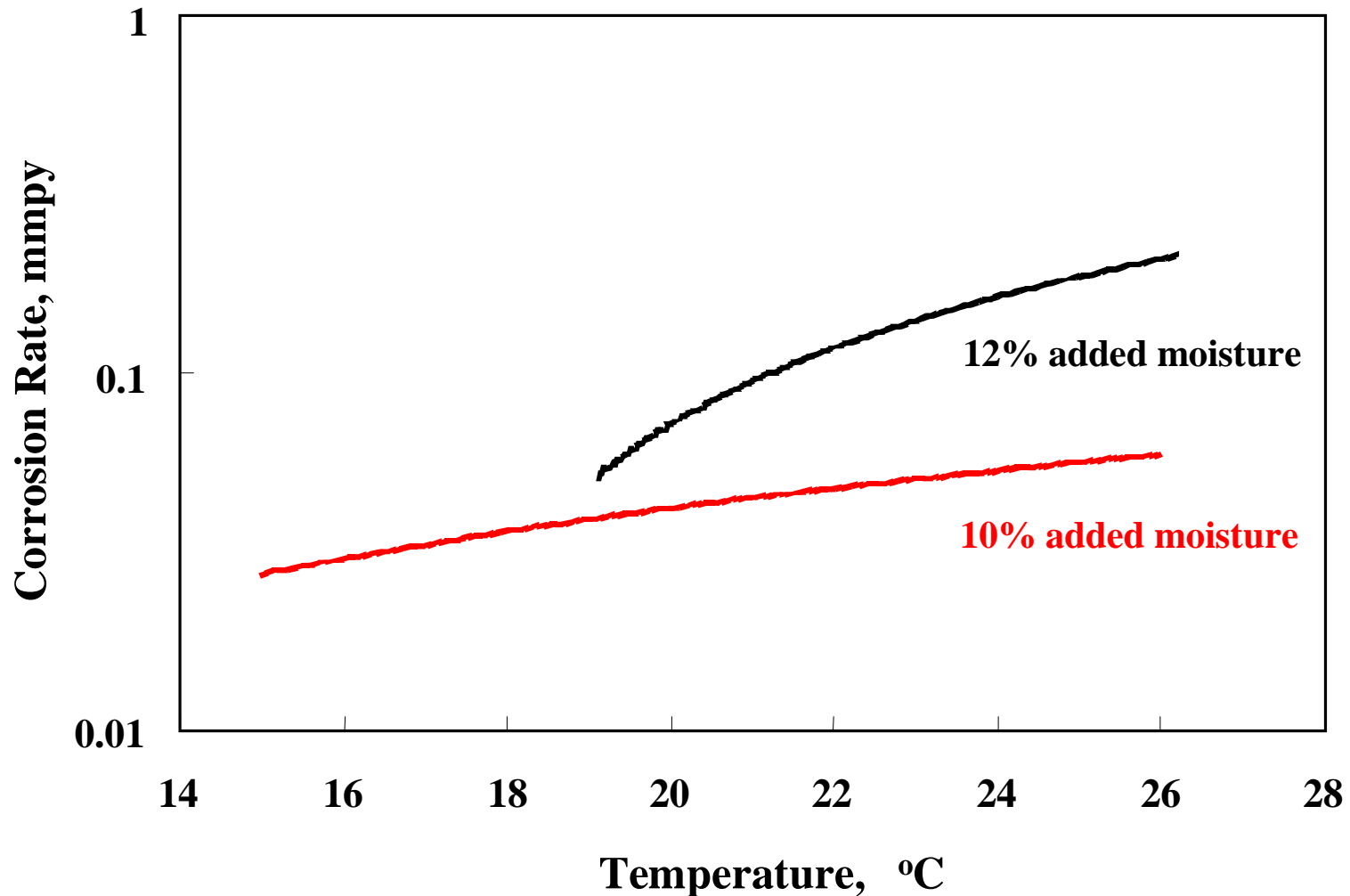


Soil + NaCl





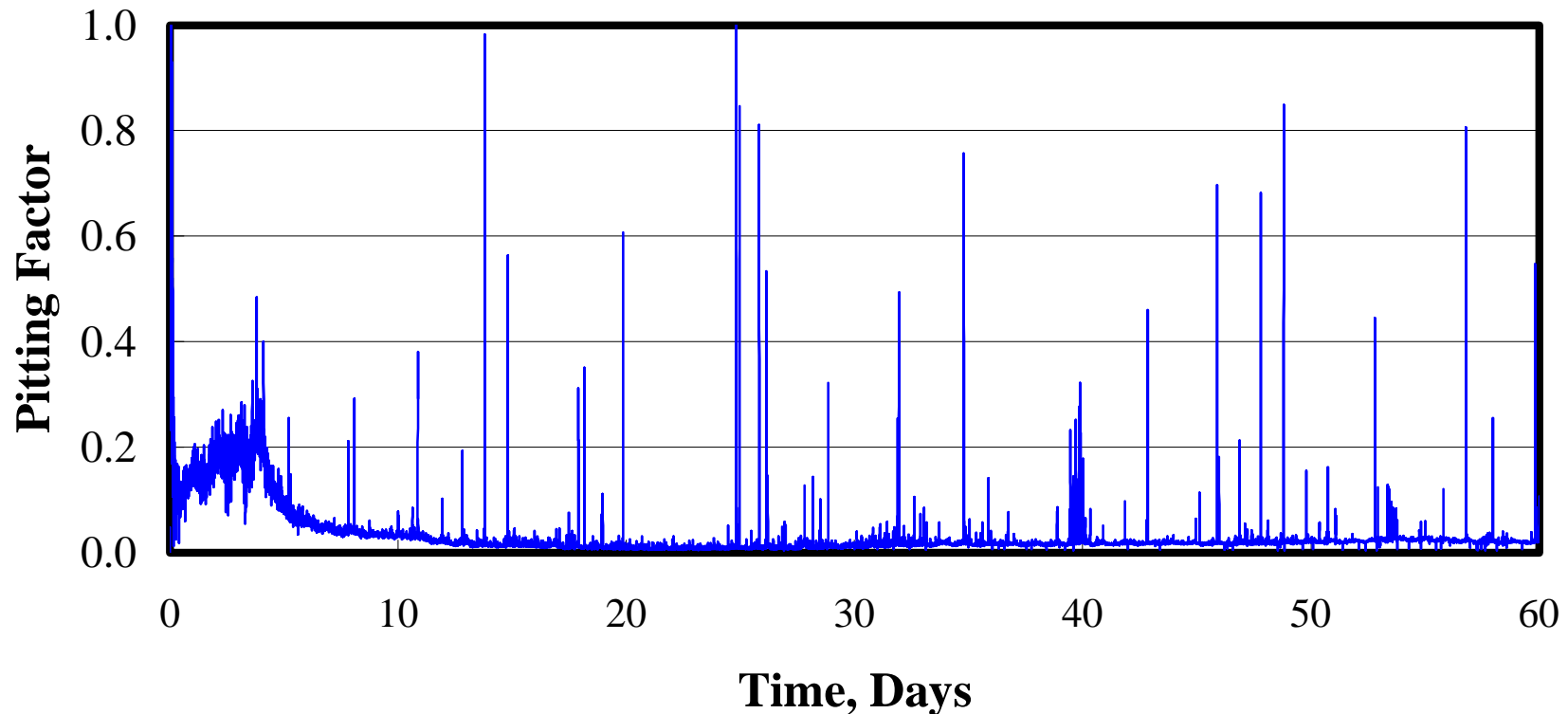
Corrosion Tests in Soil





Corrosion in Soil with NaCl

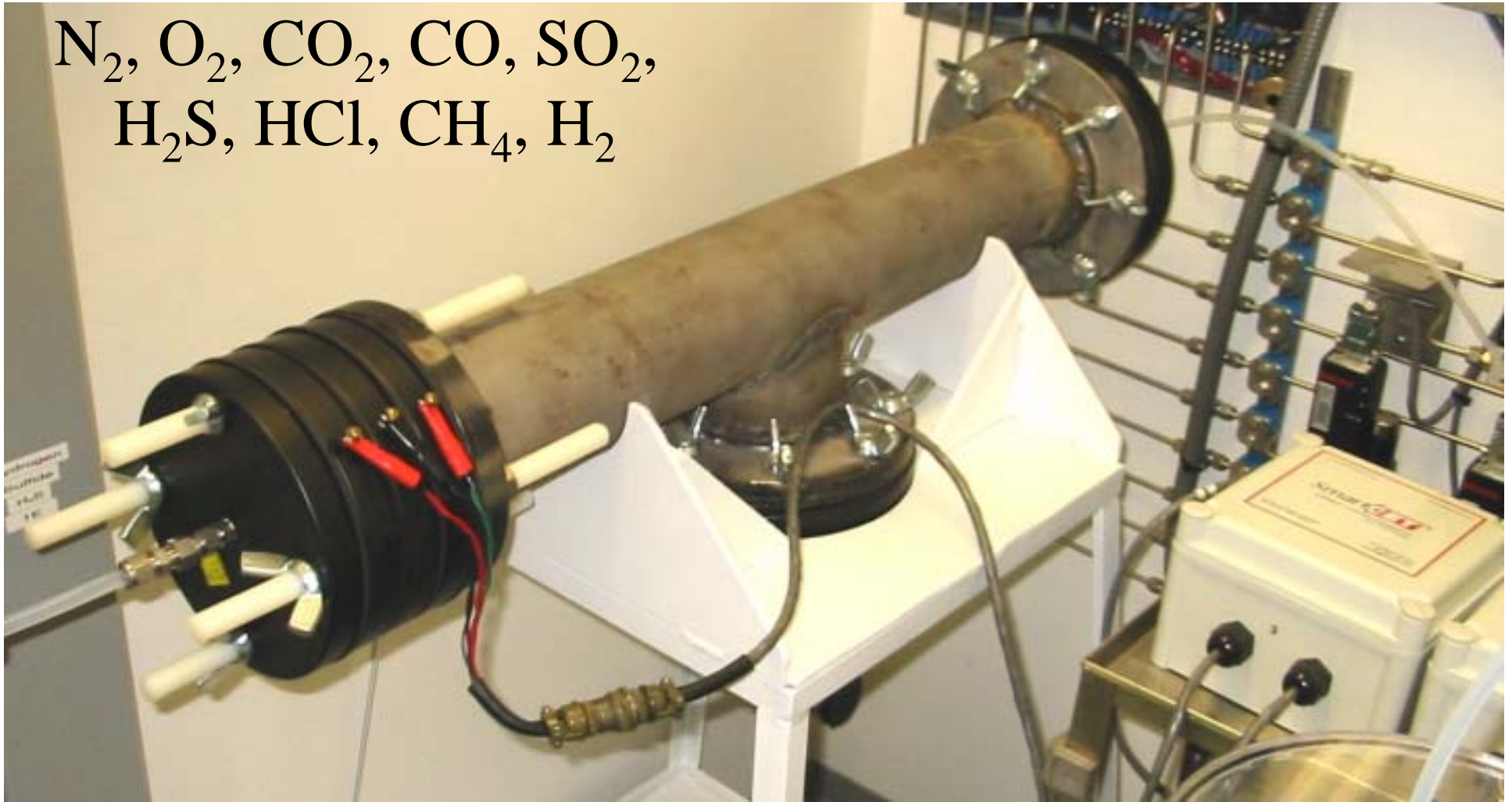
<u>Pitting Factor</u>	<u>Form of Corrosion</u>
0-0.1	General Corrosion
0.1-0.2	Tendency to Localized Corrosion/Pitting
>0.2	Localized Corrosion/Pitting





Internal Corrosion Laboratory Pipeline Tests

N_2 , O_2 , CO_2 , CO , SO_2 ,
 H_2S , HCl , CH_4 , H_2



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Conclusions

- EN able to measure corrosion rates and pitting in internal and external pipeline corrosion.
- EN sensors able to be placed using commercially accepted methods of coupons (external) or flanges and inserts (internal)



Future Work

- Miniaturize the internal corrosion probe insert for use in high pressure pipeline.
- Signal signature identification for
 - Chemistry of corrosive constituents
 - Flow regimes
 - Inhibitor effectiveness
 - Stress Corrosion Cracking
- Field Tests of EN in Gas Pipeline
 - Rocky Mountain Oilfield Testing Center (RMOTC)
 - Seeking Commercial Pipeline for Field Tests